# A Housing Energy Management Program Report

Energy
Ontario

# FINAL REPORT
# ON THE FIELD OPERATION
# OF A HIGH EFFICIENCY
# CONDENSING GAS FURNACE

REPORT No. 2C

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## SUMMARY

The Ontario Ministry of Municipal Affairs and Housing and the Consumers' Gas Company Ltd. share a mutual interest in the performance, reliability and acceptability of the new market entry models of energy-efficient condensing residential-sized gas furnaces. As a result of this mutual interest, two of these furnaces were tested over the 1981/1982/1983 heating seasons on a fifty-fifty funding basis.

The furnaces were installed in the greater Metropolitan Toronto area, one in Scarborough, one in Markham, and were compared to hard-reference electric furnaces of as near as possible equal input capacities. At each site the gas and electric furnaces were operated on a daily change-over basis, alternating operation every 24 hours over the heating seasons. This arrangement produced computable comparable data.

As the operation of an electric reference furnace can be assumed to be 100% efficient at site, a comparison of the consumptions of each furnace, when referenced to outside temperatures, will give an indication of the seasonal efficiency of the gas furnaces.

Analysis of the data gathered at the Scarborough site indicated that the energy consumption per celsius degree day for the condensing gas furnace was 14.64 MJ and for the electric reference furnace was 13.18 MJ.

Comparison of the regressed seasonal data gathered at the Scarborough site gave a calculated seasonal efficiency of 95.63%.

Steady state efficiency as determined by a DEDESCO condensing furnace efficiency flue gas analysis meter is 88%.

The calculated operating costs for each of the furnaces at this Scarborough site when referenced to 30-yr daily average temperature data, recorded at Malton airport, showed that the annual operating cost for the condensing gas furnace is $409 and for the electric furnace is $674 for a cost saving of $265 or 39% over the electric reference furnace.

Analysis of the data gathered at the Markham site indicated that the energy consumption per celsius degree day for the condensing gas furnace was 25.19 MJ and for the electric furnace was 24.13 MJ.

Comparison of the regressed data gathered at the Markham site gave a calculated seasonal efficiency of 88.70%.

Steady state efficiency as indicated by a DEDESCO condensing furnace flue gas sampling instrument is 91%.

The calculated operating costs for each of the furnaces of the Markham site when referenced to 30-yr daily average temperature data, recorded at Malton, indicated an average operating cost of $584 for the condensing gas furnace, and $992 for the electric furnace, which produced a saving of $409 or 41% over an equivalent electric furnace.

Over the period under test, both the furnaces performed in a satisfactory manner with little or no service required at either site. The units were fitted with condensate neutralizer canisters in order that the slightly acidic condensate would be rendered inactive prior to discharge into the sewage system.

The long-term effect of the slightly acidic condensate on the condensing heat exchanger is unknown at this time although the semiquantitative spectrographic analysis of the solids in the condensate showed that some nickel, chromium and iron are present in the condensate.

Overall the units performed well, and saved in both energy and operating costs over their electric counterparts.

## 1.0 INTRODUCTION

No successful industry can afford to stand still, and today, as in the past, research and development have a vital role to play in providing new products for the marketplace. Recently, a number of ultra high-efficiency, residential-sized, natural gas fueled condensing furnaces have been introduced into the marketplace by a variety of manufacturers.

The Consumers' Gas Company Ltd. and the Ontario Ministry of Municipal Affairs and Housing (M.A.H.) share a mutual interest in these new energy-efficient furnaces and decided jointly to field evaluate two models of a new market entry condensing furnace on a fifty-fifty funding basis.

This final report covers the analysis of the data, collected from both sites, over the 1982/1983 heating season. Two earlier reports entitled "High Efficiency Residential Condensing Gas Furnace Field Evaluation - Installation Report" and "High Efficiency Residential Condensing Gas Furnace Field Evaluation - Interim Report" were published in April, 1982 and March, 1983, respectively.

## 2.0 OBJECTIVE OF EVALUATION

The objective of this project is to ascertain the performance, operating costs, reliability and acceptability of a new design of condensing gas furnace.

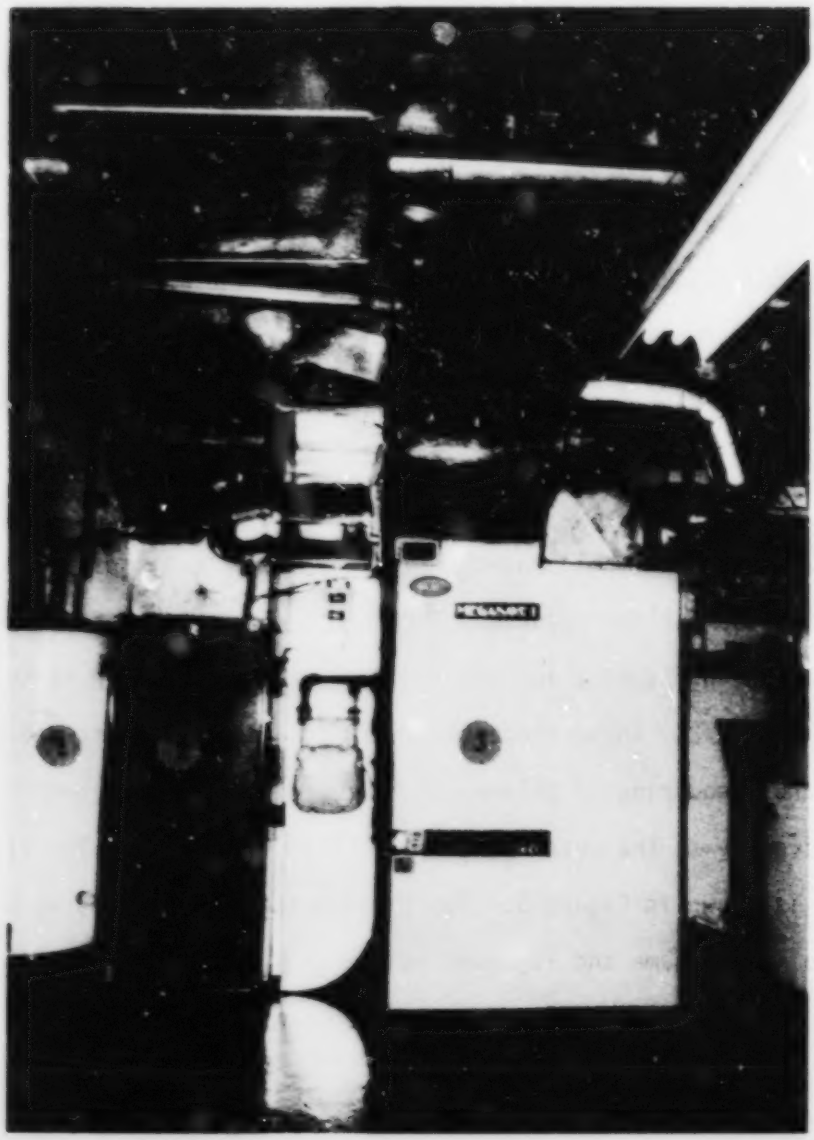
## 3.0 FURNACE SYSTEMS UNDER EVALUATION

Two models of a condensing gas furnace are installed at two different sites, one in Scarborough, Ontario and one in Markham, Ontario.

Each of the condensing gas furnaces is being compared to a hard reference electric furnace of, as near as practical, equivalent capacity to the furnace under evaluation. The systems at each site are alternated on a daily basis, with the electric furnace being operated on one day, or for a 24-h period, and the condensing gas furnace being operated on the other day, again for a 24-h period.

A comprehensive description of the furnaces under test and the test sites is given in the earlier reports. The indoor arrangement at the Scarborough site is shown in Figure 1 and the indoor arrangement at the Markham site is shown in Figure 2. These condensing gas furnaces under test are directly vented, thus requiring no chimney or flue, and the exhaust gas products are vented directly to the outside, through the nearest wall. The flue terminal is shown in Figure 3. The instrumentation utilized at both sites is virtually the same and is shown in Figure 4.

FURNACE ROOM SCARBOROUGH



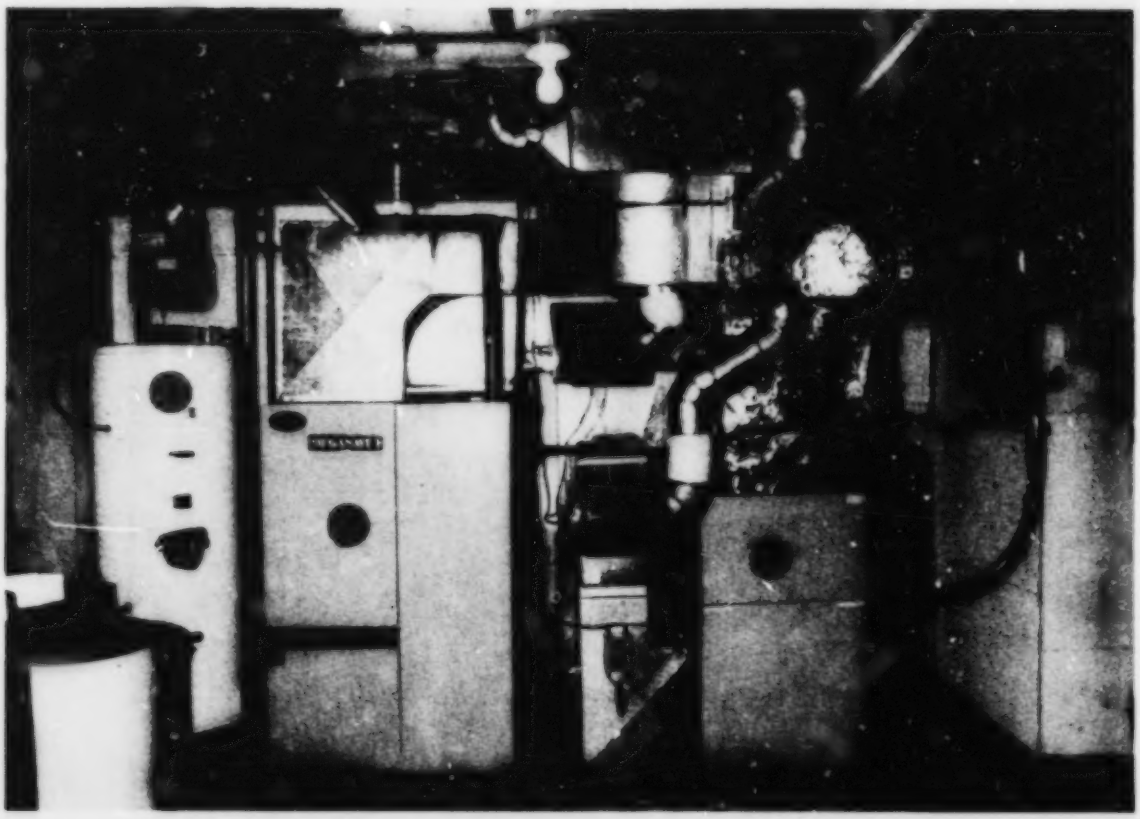
1 Gas Water Heater

2 Electric Furnace

3 Gas Furnace

FIGURE 1

FURNACE ROOM MARKHAM



1 Electric Water Heater

2 Condensing Gas Furnace

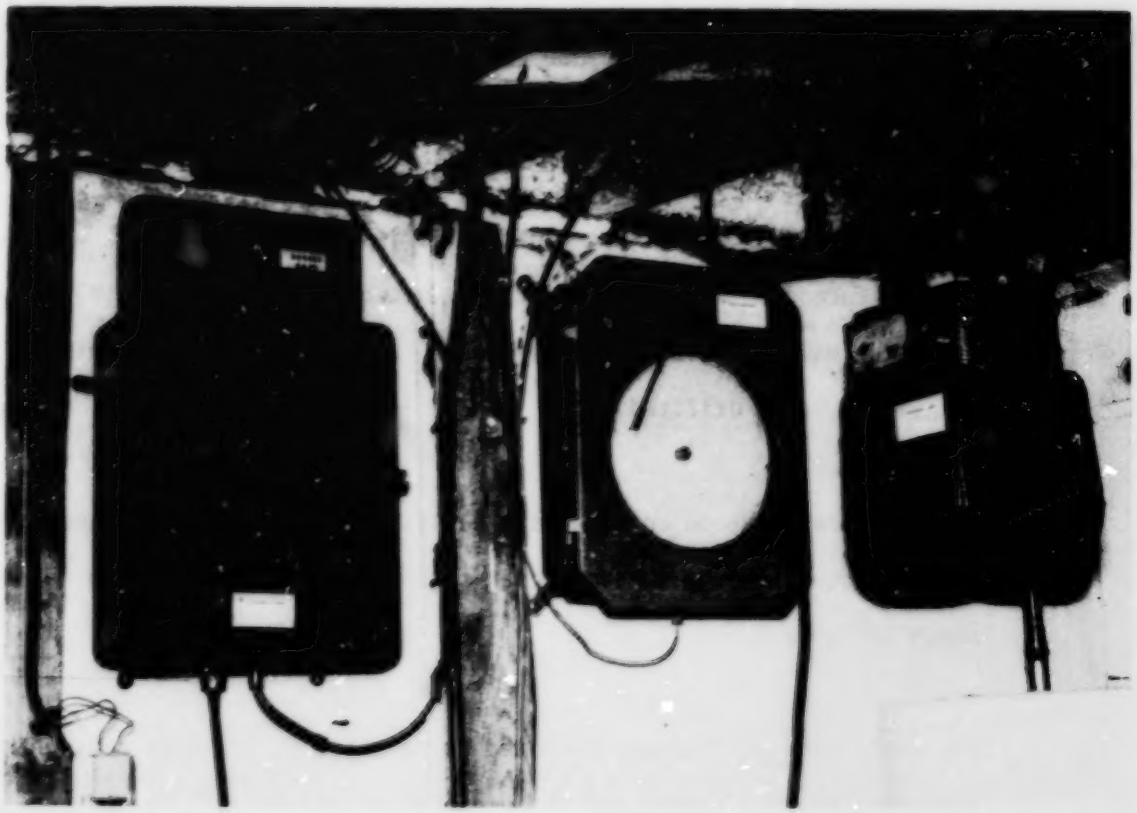
3 Existing Electric Furnace

FIGURE 2

FLUE TERMINAL

FIGURE 3

FIGURE 4



INDICATING AND RECORDING

INSTRUMENTATION - BOTH SITES

## 4.0 SITE READINGS AND RESULTS

### 4.1 Scarborough

The site at Scarborough is a two-storey semi-detached home of brick construction, with a floor area of 126 $m^2$. The existing oil furnace has been removed and replaced with a high-efficiency condensing gas furnace, of 18-kW rated input capacity. The hard-reference electric furnace of 20-kW rated input capacity is installed in parallel with the gas furnace. The interconnecting ductwork is provided with isolating dampers which are inserted or removed dependent on which furnace is being utilized.

Readings are taken on an alternate daily basis from each appliance, and the actual energy consumed over the season for each furnace is shown in Table 1.

The condensing gas furnace operated for a total of 108 days during the 1982/1983 heating season and consumed 686 $m^3$ of natural gas at the burner and 52 kW·h of electricity for the circulating air fan, for a total consumption over the period of operation of 25 709 MJ. During this period, 1 756 celsius degree days were recorded on site. The consumption per celsius degree day for this appliance is 14.64 MJ.

CONDENSING GAS FURNACE EVALUATION
SUMMARY OF 1982/1983 ACTUAL HEATING CONSUMPTION
SCARBOROUGH SITE

TABLE 1

| Month | Mean Daily Temperature (°C) | CONDENSING GAS FURNACE Electricity Consumption (kW·h) | Gas Consumption ($m^3$) | No. of Days Operating | ELECTRIC FURNACE Electricity Consumption (kW·h) | No. of Days Operating |
|---|---|---|---|---|---|---|
| October | 9.4 | 1.5 | 22.1 | 7 | 156.9 | 7 |
| November | 5.5 | 5.5 | 73.6 | 14 | 749.2 | 16 |
| December | 2.4 | 8.8 | 115.0 | 15 | 1 092.1 | 15 |
| January | -2.1 | 10.3 | 145.0 | 16 | 1 350.5 | 15 |
| February | -1.6 | 8.3 | 111.9 | 14 | 1 159.5 | 14 |
| March | 1.8 | 7.9 | 104.0 | 15 | 1 031.2 | 15 |
| April | 6.5 | 7.5 | 81.0 | 15 | 788.7 | 15 |
| May | 11.8 | 2.6 | 32.9 | 12 | 297.6 | 12 |
| Total | | 52.4 | 685.5 | 108 | 6 625.7 | 109 |
| Total (MJ) | | 25 709.1 | | | 23 850.6 | |
| Total C° Days | | 1 756.4 | | | 1 809.6 | |
| Consumption/Degree Day | | 14.64 | | | 13.18 | |

Note: From a comparison of the consumptions per degree day the seasonal efficiency of the condensing gas furnace is calculated to be 90.03%

The electric furnace, which can be assumed to be 100% efficient at site, consumed 6 626 kW·h of electrical energy over a period of 109 days during the 1982/1983 heating season. During this period, the site recorded celsius degree days were 1 810, to give an energy consumption per celsius degree day of 13.18 MJ. Comparing these figures gives a seasonal efficiency for the condensing gas furnace of 90.03%.

The daily energy consumption recorded at site for each furnace is plotted against daily mean outside temperature to produce a linear regression graph for each appliance. This regression is shown in Figure 5. The dotted line is the consumption of the gas furnace and the solid line is the consumption of the electric furnace. Both lines have similar slopes and similar intercepts, illustrating that their fuel consumptions at site are very close. With the electric furnace being assumed 100% efficient at site, the comparison of the slopes will give an indication of seasonal efficiency. This is calculated to be 95.63%. From both these analyses and the degree day analysis, it appears that the seasonal efficiency of this new model of high efficiency condensing gas furnace is in the range of 90.03% - 95.63%. This compares favourably with the manufacturer's claim that this furnace has an operating efficiency under laboratory conditions of about 94.00%.

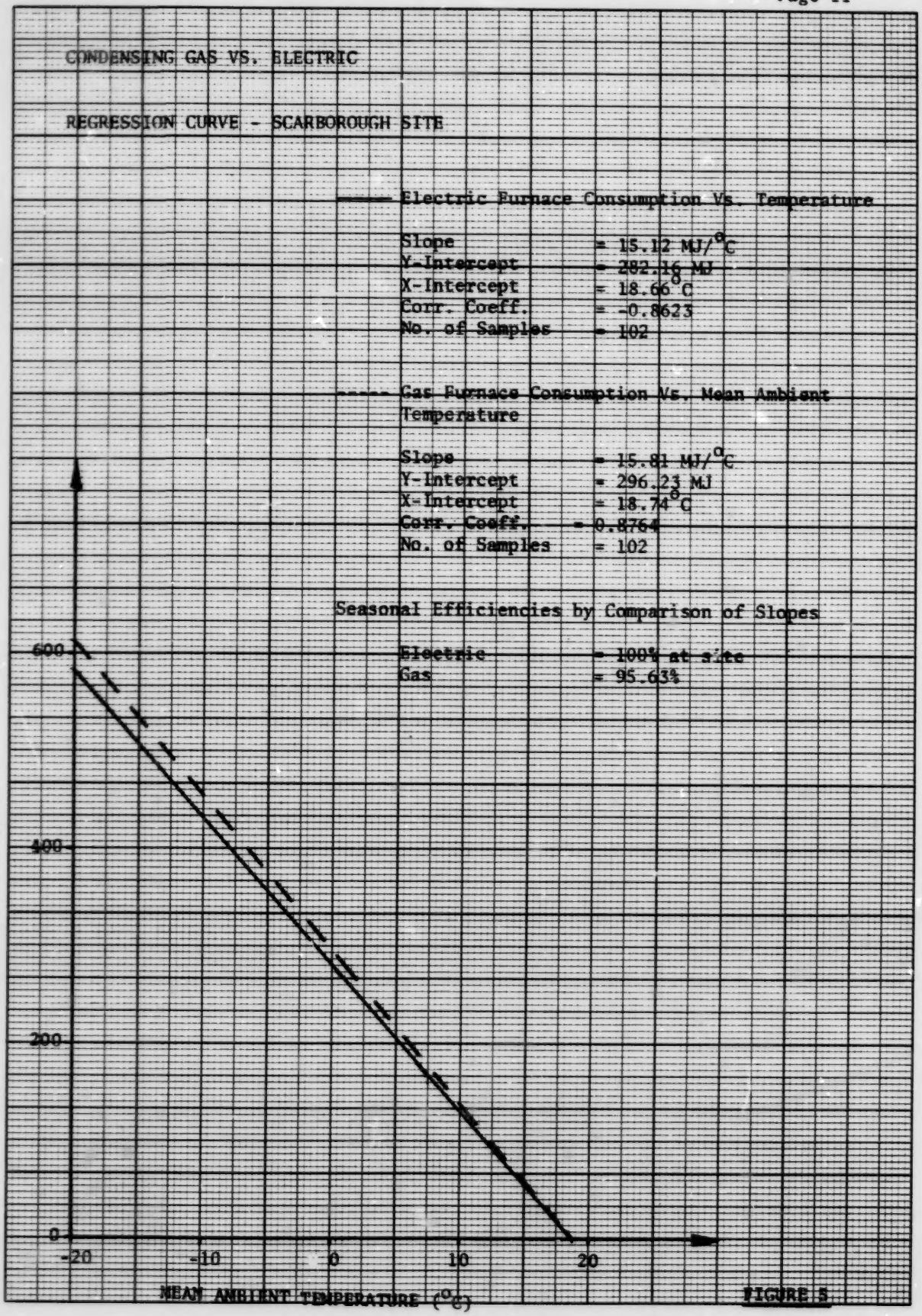

CONDENSING GAS VS. ELECTRIC
REGRESSION CURVE - SCARBOROUGH SITE
Electric Furnace Consumption Vs. Temperature
Slope = 15.12 MJ/°C
Y-Intercept = 282.16 MJ
X-Intercept = 18.66 °C
Corr. Coeff. = -0.8623
No. of Samples = 102
Gas Furnace Consumption Vs. Mean Ambient Temperature
Slope = 15.81 MJ/°C
Y-Intercept = 296.23 MJ
X-Intercept = 18.74 °C
Corr. Coeff. = 0.8764
No. of Samples = 102
Seasonal Efficiencies by Comparison of Slopes
Electric = 100% at site
Gas = 95.63%
600
400
200
0
-20
-10
0
10
20
ENERGY CONSUMPTION (MJ)
MEAN AMBIENT TEMPERATURE (°C)

FIGURE 5

The steady state efficiency at the Scarborough site was measured several times with a direct reading DEDESCO flue gas analysis condensing furnace efficiency meter, which has the capability of estimating the combustion efficiency of condensing furnaces. The average of the analyses from this instrument are shown below:

| | |
|---|---|
| Steady state efficiency | 88%* |
| Carbon dioxide ($CO_2$) | 4.6% |
| Oxygen ($O_2$) | 12.9% |
| Exhaust gas temperature (Te) | 67°C |
| Differential between room and actual exhaust | |

Table 2 shows the actual operating costs for each furnace, gas and electric, for that period of the heating season which each individually supplies tempered air to the dwelling. The cost to operate the condensing gas furnace for a period of 108 days is $158, and to operate the electric furnace for 109 days is $254, for a combined seasonal total cost of $411 for the complete period of the test -- a total of 217 days.

*The Dedesco analyser readings should be viewed with some caution. The instrument computer assumes that the flue gases are fully saturated and it calculates the efficiency on this assumption. If the flue gases sampled are not fully saturated, the meter will read low. From the figures obtained and quoted it appears that the flue gases were not saturated at the time the samples were taken.

FURNACE EVALUATION
SUMMARY OF 1982/1983 ACTUAL HEATING COSTS*
SCARBOROUGH SITE

TABLE 2

| Month | CONDENSING GAS FURNACE | | | ELECTRIC FURNACE |
|---|---|---|---|---|
| | Electricity Cost ($) | Gas Cost ($) | Subtotal ($) | Electricity Cost ($) |
| October | 0.06 | 5.02 | 5.08 | 6.01 |
| November | 0.21 | 16.72 | 16.93 | 28.69 |
| December | 0.34 | 26.11 | 26.45 | 41.83 |
| January | 0.40 | 32.92 | 33.32 | 51.72 |
| February | 0.32 | 25.40 | 25.72 | 44.41 |
| March | 0.30 | 23.60 | 23.90 | 39.49 |
| April | 0.29 | 18.39 | 18.68 | 30.21 |
| May | 0.10 | 7.46 | 7.56 | 11.40 |
| Total | 2.02 | 155.62 | 157.64 | 253.76 |

*Costs calculated using rates of 22.7¢/m³ for gas, and 3.83¢/kW·h for electricity.

In order to ascertain the operating cost for each furnace, had they operated individually throughout the 1982/1983 heating season, the consumption information generated by the regression analysis was applied to the daily average outside temperatures, gathered at site, for the period September 15, 1982, to May 15, 1983. Table 3 shows the annual heating season consumptions, the annual heating season costs and the cost savings of one furnace over the other. The condensing gas furnace consumes 120 kW·h of electricity for the blower motor and 1 607 $m^3$ of natural gas fuel, against 15 931 kW·h for the electric furnace. Using the tail-end energy rates of 22.7¢/$m^3$ for gas and 3.83¢/kW for electricity, indicates that the seasonal cost for the gas furnace is $369 as opposed to $610 for the electric furnace. In other words, the operating cost of a high efficiency gas furnace is $241 less than that cost required to operate a comparable electric furnace -- a saving of 39%.

As 1982/1983 cannot be considered a typical year, the site-generated data is computed with the 30-yr daily average temperatures recorded at Malton Airport to arrive at average seasonal consumptions and costs. These are shown in Table 4. All calculations are made by using daily mean temperatures and the monthly figures are compiled by adding the daily consumption for each month. The monthly mean temperatures are made by adding the daily means. The estimated consumptions are used to compute the annual operating costs of $409 for the condensing

FURNACE EVALUATION
1982/1983 COMPUTED SEASONAL HEATING COSTS*
SCARBOROUGH SITE

TABLE 3

| Month | Mean Daily Temp. (°C) | CONSUMPTION/MONTH | | | COST/MONTH | | | |
|---|---|---|---|---|---|---|---|---|
| | | GAS FURNACE | | ELECTRIC FURNACE | GAS FURNACE | | ELECTRIC FURNACE | |
| | | Electricity (kW·h) | Gas ($m^3$) | Electricity (kW·h) | Electricity ($) | Gas ($) | Electricity ($) | Savings ($) |
| September | 14.9 | 4.6 | 5.14 | 504.8 | 0.18 | 11.67 | 19.33 | 7.48 |
| October | 9.6 | 9.5 | 119.6 | 1 182.4 | 0.36 | 27.15 | 45.29 | 17.78 |
| November | 5.7 | 12.5 | 165.3 | 1 637.4 | 0.48 | 37.52 | 62.71 | 24.71 |
| December | 1.4 | 16.6 | 226.2 | 2 245.1 | 0.64 | 51.35 | 85.99 | 34.00 |
| January | -3.2 | 20.6 | 287.1 | 2 849.9 | 0.79 | 65.17 | 109.15 | 43.19 |
| February | -2.1 | 17.7 | 245.7 | 2 438.2 | 0.68 | 55.77 | 93.38 | 36.93 |
| March | 1.2 | 16.8 | 229.3 | 2 274.5 | 0.64 | 52.05 | 87.11 | 34.42 |
| April | 5.3 | 12.8 | 120.4 | 1 687.8 | 0.49 | 38.68 | 64.64 | 25.47 |
| May | 10.1 | 9.0 | 112.4 | 1 111.0 | 0.34 | 25.52 | 42.55 | 16.69 |
| Subtotal | | | | | 4.60 | 364.88 | | |
| Total | | 120.1 | 1 607.4 | 15 931.1 | 369.48 | | 610.15 | 240.67 |

*Consumptions computed from mean daily temperatures and regression equations shown in Figure 5, and rates of 22.7¢/$m^3$ for gas and 3.83¢/kW·h for electricity.

FURNACE EVALUATION
30-YR. AVERAGE COMPUTED SEASONAL COSTS*
SCARBOROUGH SITE

TABLE 4

| Month | Mean Monthly Temp. (From 30-Yr. Daily (°C) | CONSUMPTION/MONTH | | | COST/MONTH | | | |
|---|---|---|---|---|---|---|---|---|
| | | GAS FURNACE | | ELECTRIC FURNACE | GAS FURNACE | | ELECTRIC FURNACE | |
| | | Electricity (kW·h) | Gas ($m^3$) | Electricity (kW·h) | Electricity ($) | Gas ($) | Electricity ($) | Savings ($) |
| September | 15.5 | 4.17 | 40.79 | 398.36 | 0.16 | 9.26 | 15.26 | 5.84 |
| October | 9.3 | 9.73 | 123.25 | 1 218.95 | 0.37 | 27.98 | 46.69 | 18.34 |
| November | 3.3 | 14.43 | 195.53 | 1 938.63 | 0.55 | 44.38 | 74.25 | 29.32 |
| December | -3.5 | 20.88 | 290.69 | 2 885.64 | 0.80 | 65.99 | 110.52 | 43.73 |
| January | -6.7 | 23.67 | 332.43 | 3 301.06 | 0.91 | 75.46 | 126.43 | 50.06 |
| February | -6.1 | 20.89 | 292.82 | 2 907.55 | 0.80 | 66.47 | 111.34 | 44.07 |
| March | -1.0 | 18.66 | 257.53 | 2 555.50 | 0.72 | 58.46 | 97.88 | 38.70 |
| April | 6.2 | 12.02 | 158.52 | 1 570.26 | 0.46 | 35.98 | 60.14 | 23.70 |
| May | 12.3 | 7.09 | 84.01 | 828.32 | 0.27 | 19.07 | 31.72 | 12.38 |
| Total | | 131.54 | 1 775.57 | 17 604.27 | 5.04 | 403.05 | | 266.14 |
| Total Operating Cost | | | | | 408.09 | | 674.23 | |

*Consumption data computed from 30-yr. mean daily temperatures and regression equations shown in Figure 5. Costs based on rates of 22.7¢/$m^3$ for gas, and 3.83¢/kW·h for electricity.

gas furnace and $674 for the electric furnace, for a cost saving of $266, or 39.00% which is constant with the previous real data.

## 4.2 Markham

The home at Markham is a bungalow having a total heated area of 284 m². The site is unaltered from last season in that the existing, original electric furnace of 25 kW rated capacity is used as the hard reference and the new, condensing gas furnace at 23.44 kW rated input capacity is the appliance under test.

The data produced from the Markham site is treated in a similar manner to that produced at Scarborough, in that the real data is used to draw the regression graphs and the graphs are used to predict the average seasonal energy usage and operating costs for both systems.

Table 5 shows the actual energy consumptions for each appliance, this being 31 387 MJ for the condensing gas furnace over a period of 78 operating days when data was collected, and 30 676.3 MJ for the electric furnace over a period of 79 operating days when data was collected. Celsius degree days over these periods is 1 246 and 1 271 respectively, which gives a consumption rate of 25.19 MJ per celsius degree day for the condensing gas furnace and 24.13 MJ per celsius degree day for the electric furnace. A comparison of these rates indicates a seasonal efficiency of 95.80%, again very close to the manufacturer's claims.

CONDENSING GAS FURNACE EVALUATION
SUMMARY OF 1982/1983 ACTUAL HEATING CONSUMPTION*
MARKHAM SITE

TABLE 5

| Month | Mean Daily Temperature (°C) | CONDENSING GAS FURNACE Electricity Consumption (kW·h) | Gas Consumption ($m^3$) | Number of Days Operating | ELECTRIC FURNACE Electricity Consumption (kW·h) | Number of Days Operating |
|---|---|---|---|---|---|---|
| September | 7.8 | 7.9 | 48.3 | 7 | 271.8 | 7 |
| October | 7.3 | 3.3 | 32.5 | 4 | 368.3 | 4 |
| November | 4.5 | 4.1 | 61.4 | 8 | 1 120.6 | 10 |
| December | 2.5 | 6.9 | 206.2 | 12 | 1 608.1 | 11 |
| January | -2.7 | 10.6 | 199.9 | 14 | 1 652.4 | 14 |
| February | -1.9 | 9.2 | 169.7 | 13 | 2 067.1 | 14 |
| March | 4.9 | 0.5 | 6.3 | 1 | 181.0 | - |
| April | 7.2 | 5.3 | 84.7 | 11 | 852.0 | 11 |
| May | 10.8 | 1.6 | 29.3 | 8 | 299.9 | 8 |
| Total | | 49.4 | 838.3 | 78 | 8 521.2 | 79 |
| Total (MJ) | | 887.7 | 3 138.7 | | 30 676.3 | |
| Total C° Days | | | 1 246 | | 1 271.3 | |
| Consumption/Degree Day (MJ/C°D) | | | 25.19 | | 24.13 | |

Note: From a comparison of the consumptions per degree day, the seasonal efficiency of the condensing gas furnace is calculated to be 95.8%

Steady state efficiency and flue gas analysis taken with the DEDESCO indicating instrument are:

| | |
|---|---|
| Steady state efficiency | 91.00% |
| Carbon dioxide ($CO_2$) | 6.70% |
| Oxygen ($O_2$) | 9.20% |
| Flue gas temperature (Te) | 57°C |

Figure 6 shows the regression lines for both furnaces -- the dotted line representing the condensing gas furnace consumption and the solid line representing the electric furnace consumption. Because the number of samples is relatively small and the correlation factor is quite low in this case, less confidence can be placed in these plots as compared to the plots generated from the Scarborough data. This is borne out by the fact that both lines do not pass through the same reference point. Because the electric furnace consumption should follow the house load line, the reference point for this line would be expected to be lower than that for the gas furnace and although the slope is less, it indicates a higher efficiency than the gas furnace. This regression data must be interpreted with a little less confidence than that produced from the Scarborough site. An analysis of the slopes of the regression graph at the Markham site indicates a seasonal efficiency of 88.70%.

CONDENSING GAS AND ELECTRIC FURNACE

REGRESSION CURVES - MARKHAM SITE

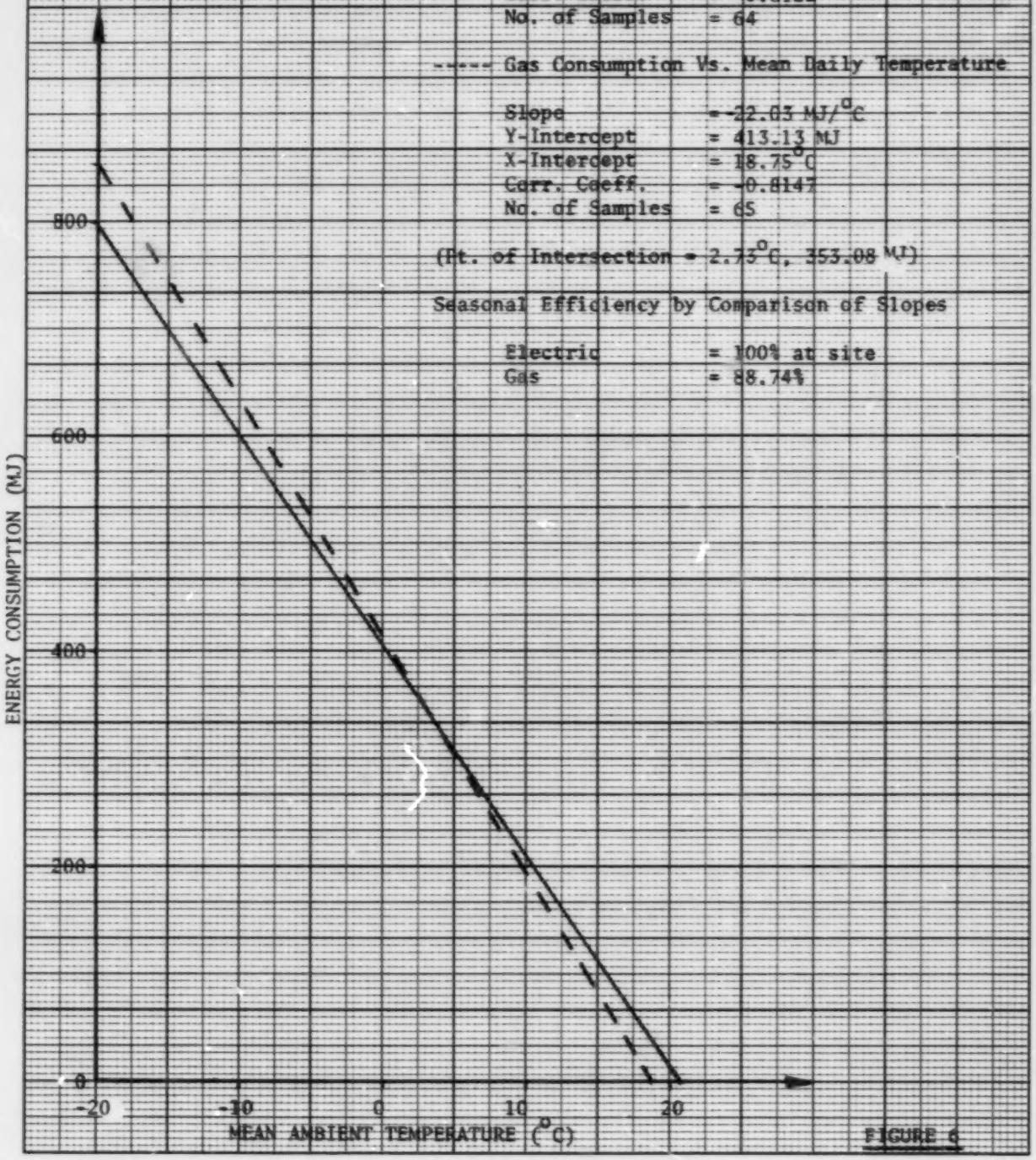



FIGURE 6

Table 6 shows the actual energy costs incurred by each furnace at the site for the respective operating periods of 78 and 79 days. The operating costs of the gas furnace and the electric furnace is $169 and $316 respectively.

This data, extrapolated for the full 1982/1983 heating season for each furnace, gives annual operating costs of $518 and $884 for the gas and electric furnaces respectively, a savings of $367 or 41.00% for the gas furnace. The savings would be expected to be lower than at the Scarborough site because the Markham home has an electric water heater, thereby eliminating one flue opening. These results are shown in Table 7.

The annualized 30-yr average operating costs are shown in Table 8, which indicates the average cost of operating either of these furnaces independently at this site would be $584 for the condensing gas furnace and $992 for the electric furnace, a significant saving of $409 or 41.10%.

FURNACE EVALUATION
SUMMARY OF 1982/1983 ACTUAL HEATING COSTS*
MARKHAM SITE

TABLE 6

| Month | CONDENSING GAS FURNACE | | | ELECTRIC FURNACE |
|---|---|---|---|---|
| | Electricity Cost ($) | Gas Cost ($) | Subtotal ($) | Electricity Cost ($) |
| September | 0.30 | 10.56 | 10.86 | 10.41 |
| October | 0.13 | 6.63 | 6.76 | 14.11 |
| November | 0.16 | 14.69 | 14.85 | 36.26 |
| December | 0.26 | 24.42 | 24.68 | 100.63 |
| January | 0.41 | 42.95 | 43.36 | 63.27 |
| February | 0.42 | 40.95 | 41.37 | 71.88 |
| March | 0.92 | 1.00 | 1.02 | - |
| April | 0.20 | 18.59 | 18.79 | 29.50 |
| May | 0.06 | 7.29 | 7.35 | 14.63 |
| Total | 22.86 | 167.08 | 169.04 | 316.17 |

*These costs have been calculated based on rates of 227¢/m³ for gas and 3.83¢/kW·h for electricity.

FURNACE EVALUATION
1982/1983 COMPUTED SEASONAL HEATING COSTS*
MARKHAM SITE

TABLE 7

| Month | Mean Daily Temp. (°C) | CONSUMPTION/MONTH | | | COST/MONTH | | | |
|---|---|---|---|---|---|---|---|---|
| | | GAS FURNACE | | ELECTRIC FURNACE | GAS FURNACE | | ELECTRIC FURNACE | |
| | | Electricity (kW·h) | Gas ($m^3$) | Electricity (kW·h) | Electricity ($) | Gas ($) | Electricity ($) | Savings ($) |
| September | 14.9 | 11.8 | 77.6 | 968.0 | 0.45 | 17.62 | 37.07 | 19.00 |
| October | 9.6 | 16.7 | 173.4 | 1 886.6 | 0.64 | 39.36 | 72.26 | 32.26 |
| November | 5.4 | 19.7 | 241.9 | 2 534.7 | 0.75 | 54.91 | 97.08 | 41.42 |
| December | 2.2 | 23.1 | 308.2 | 3 124.8 | 0.88 | 69.96 | 119.7 | 48.86 |
| January | -2.8 | 27.4 | 400.4 | 3 944.4 | 1.05 | 90.89 | 151.07 | 59.13 |
| February | -3.1 | 24.1 | 366.6 | 3 633.5 | 0.92 | 83.22 | 139.16 | 55.02 |
| March | 2.4 | 23.0 | 307.4 | 3 103.2 | 0.88 | 69.78 | 118.85 | 48.19 |
| April | 7.0 | 18.3 | 213.5 | 2 246.2 | 0.70 | 48.46 | 86.03 | 36.87 |
| May | 10.7 | 15.2 | 148.0 | 1 643.3 | 3.45 | 33.60 | 62.94 | 25.89 |
| Subtotal | | | | | 9.72 | 507.80 | | |
| Total | | 179.3 | 2 237.0 | 23 084.7 | 517.52 | | 884.16 | 366.64 |

*Computed from regression analyses shown in Figure 6, and rates of 22.7¢/$m^3$ for gas and 3.83¢/kW·h for electricity.

FURNACE EVALUATION
30-YR. AVERAGE COMPUTED SEASONAL COSTS*
MARKHAM SITE

TABLE 8

| Month | Mean Monthly Temperature (From 30-Yr. Daily (°C) | CONSUMPTION/MONTH | | | COST/MONTH | | | |
|---|---|---|---|---|---|---|---|---|
| | | GAS FURNACE | | ELECTRIC FURNACE | GAS FURNACE | | ELECTRIC FURNACE | |
| | | Electricity (kW·h) | Gas ($m^3$) | Electricity (kW·h) | Electricity ($) | Gas ($) | Electricity ($) | Savings ($) |
| September | 15.5 | 11.6 | 62.8 | 861.3 | 0.44 | 14.26 | 32.99 | 18.29 |
| October | 9.3 | 17.2 | 178.5 | 1 933.8 | 0.66 | 40.52 | 74.06 | 32.88 |
| November | 3.3 | 21.6 | 279.6 | 3 852.9 | 0.83 | 63.47 | 109.27 | 44.97 |
| December | -3.5 | 28.1 | 413.1 | 4 088.9 | 1.08 | 93.77 | 156.60 | 61.75 |
| January | -6.7 | 30.8 | 471.5 | 4 626.0 | 1.18 | 107.03 | 177.18 | 68,97 |
| February | -6.1 | 27.3 | 415.5 | 4 082.6 | 1.05 | 94.32 | 156.36 | 60.99 |
| March | -1.0 | 25.9 | 366.6 | 3 662.0 | 0.99 | 83.22 | 140.26 | 56.05 |
| April | 6.2 | 19.2 | 227.7 | 2 376.6 | 0.74 | 51.69 | 91.02 | 38.59 |
| May | 12.3 | 14.7 | 123.6 | 1 428.8 | 0.56 | 28.06 | 54.72 | 26.10 |
| Total | | 196.4 | 2 538.9 | 25 912.9 | 7.53 | 576.34 | | 408.59 |
| Total Operating Cost | | | | | 583.87 | | 992.46 | |

*Costs computed from regression analyses shown in Figure 6 and Table 6, using daily average temperatures for 1951/1980 and rates of 22.7¢/$m^3$ for gas and 3.83¢/kW·h for electricity.

rd3/ea

## 5.0 COMMENT ON THE FUNCTIONAL OPERATION

The operational performance of this new design of natural gas fueled condensing furnace is completely satisfactory. At the Scarborough site, no service was required on the furnace. The Markham site experienced a "no heat" service call for the replacement of a defective relay. While this may have been an isolated incident, the approved contractor took over 8 hours to diagnose and rectify the defect. This situation could indicate that the servicing and maintenance of these more complex, high-efficiency condensing furnaces will require that service contractors be retrained to become more skillful in diagnosing furnace faults.

Both sites were retrofitted under warranty by the manufacturer with flame roll-out switches to detect spillage should it occur. To date, no spillage at either site has been detected.

The Scarborough site is fitted with a "Thermojet" outside air inlet which supplies fresh outside air to the cold air return plenum. This device was fitted because the homeowner had complained of stagnant air in the home. No further adverse comments were received from the homeowner after this device was installed.

Comparing the 1982/1983 data with that gathered from part of the 1981/1982 heating season data, it is confirmed that the Scarborough site again experienced a higher efficiency than the Markham site.

The calculated seasonal efficiency at the Scarborough site is higher than the indicated steady-state efficiency by almost 7.00%, which is a wide spread and the differential is in the reverse of the expected order. The seasonal efficiency and steady-state efficiency figures obtained from the Markham site are much closer at 2.30% and are in the expected order.

Two comments are worth noting by way of explanation.

1. The regression analysis is not absolute as it forces the graph to be linear thereby introducing an element of variation.

2. The DEDESCO condensing furnace efficiency analyser has a built in feature which assumes that the sample extracted from the flue is saturated and the computer in the analyser calculates the efficiency using this assumption. In reality the flue gas sample may not be saturated and if this is the case the instrument will assume a higher stack loss and provide a lower steady-state efficiency number.

Notwithstanding the above, the seasonal and steady-state efficiency numbers provided through the field analysis can be considered representative of the real world situation.

Comparing operating costs, the savings over the electric furnaces are similar at both sites over the two seasons of the field testing.

| Site | Computed 30-yr Average % Seasonal Saving 1981/1982 | Computed 30-yr Average % Seasonal Saving 1982/1983 |
|---|---|---|
| Scarborough | 36 | 39 |
| Markham | 39 | 41 |

The average annual operating cost of a typical conventional standing pilot, atmospheric burner, gas warm-air furnace, in the Metropolitan Toronto area is approximately $859. The high-efficiency furnace under test would have calculated average operating cost advantages over a conventional gas furnace of about 29% and about 46% over a conventional oil furnace at assumed seasonal efficiencies of 65% respectively.

Visual examination of both furnaces revealed little or no deterioration of those furnace components which are accessible without dismantling the furnaces, however both sites have two local corrosion spots inside the front access door directly opposite the exhaust blower mounting bolts. This condition is shown in Figure 7 and is believed to be an isolated abberation with this model of furnace tested. It would appear that the exhaust products are seeping past the exhaust blower motor cooling appertures and condensing out on the cover. The condition may also be aggravated due to an electrical discharge eminating from the motor hold down bolts, causing galvanic corrosion. A small electrical discharge was measured from the hold down bolts to ground at one of the sites. Newer models of the furnaces under test have different exhaust blower motors which have eliminated this condition.

INSIDE OF ACCESS PANEL

SCARBOROUGH SITE

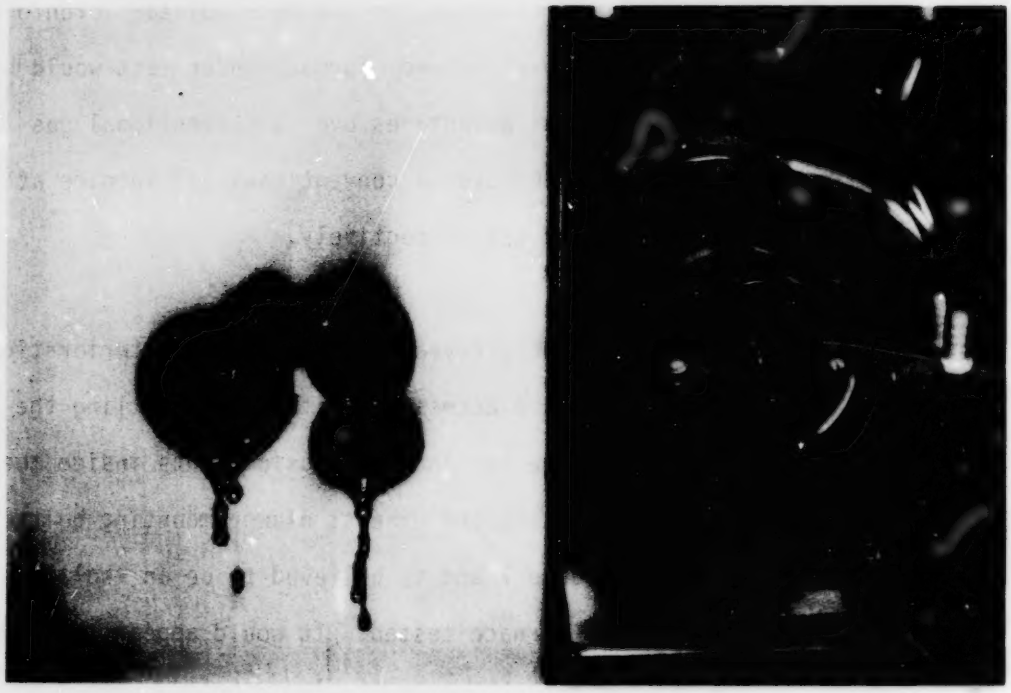


FIGURE 7

Analyses of the condensates were conducted to determine whether the mildly acidic condensate may cause erosion or corrosion on the condensing heat exchanger. The results of these analyses are shown in Figure 8 and 9 for the Scarborough and Markham sites respectively.

Both analyses show that there is chromium and nickel solids in the condensate. This aspect requires further investigation at a later date, if possible.

SPECTROGRAPHIC ANALYSIS OF CONDENSATE

SCARBOROUGH SITE

SEMIQUANTITATIVE SPECTROGRAPHIC

SAMPLE(S) FROM The Consumers' Gas Company Ltd.
P.O. Box 650
Scarborough, Ontario
M1K 5E3

SAMPLES(S) OF CONDENSATE SOLUTION

| | Sample | | Sample |
|---|---|---|---|
| Aluminum ($Al_2O_3$) | .2% | Manganese | .4% |
| Chromium | M-H | Molybdenum | .3% |
| Cobalt | .05% | Nickel | .5-1% |
| Copper | .05% | Silicon ($SiO_2$) | .5% |
| Iron (Fe) | H | Titanium | .05% |
| | | Vanadium | .5% |
| | | Zinc | .2% |
| | | Zirconium ($ZrO_2$) | .01% |

Figures are approximate:

CODE

H - High - 10 - 100% approx.
M - Medium - 1 - 10% approx.
L - Low - 1 - 1% approx.

- Not Detected - Elements looked for but not found
X Not looked For
Less Than

PH OF SOLUTION 4.5

FIGURE 8

SPECTROGRAPHIC ANALYSIS OF CONDENSATE

MARKHAM SITE

SEMIQUANTITATIVE SPECTROGRAPHIC

SAMPLE(S) FROM The Consumers' Gas Company Ltd.
P.O. Box 650
Scarborough, Ontario
M1K 5E3

SAMPLES(S) OF CONDENSATE SOLUTION

| | Sample #1 | | Sample #1 |
|---|---|---|---|
| Aluminum ($Al_2O_3$) | M 5% | Manganese | .1% |
| Antimony | 0.3% | Magnesium (MgO) | .5% |
| Barium | .01% | Molybdenum | .01% |
| Boron | .01% | Nickel | .5% |
| Calcium (CaO) | .5% | Silver | .0005% |
| Chromium | 1-2% | Silicon ($SiO_2$) | H |
| Cobalt | .01% | Sodium ($Na_2O$) | 1% |
| Copper | .02% | Thorium ($ThO_2$) | .02% |
| Germanium | .001% | Tin | .2% |
| Iron (Fe) | 2% | Uranium ($U_3O_6$) | .01% |
| Lead | .02% | Ytrium ($Y_2O_3$) | .05% |
| | | Zinc | .002% |

Figures are approximate:

CODE

H - High - 10 - 100% approx.
M - Medium - 1 - 10% approx.
L - Low - 1 - 1% approx.

\- Not Detected - Elements looked for but not found
X Not looked For
Less Than

PH OF SOLUTION 5.1

FIGURE 9

## 6.0 CONCLUSIONS

(a) During the period under test these new model furnaces operated in a reliable and acceptable manner.

(b) The condensing gas furnace is highly efficient and has a lower operating cost than an equivalent electric furnace.

(c) The unit installed at the Scarborough site produced an indicated seasonal efficiency in the range of 90.03% to 95.60% with seasonal cost savings of $266, or 39%, when compared to an electric furnace.

(d) The appliance installed at the Markham site produced an indicated seasonal efficiency in the range of 88.70% to 95.80% with seasonal cost savings of $409, or 41%, when compared to an electric furnace.

## 7.0 RECOMMENDATION

The field evaluations will be terminated and the sites restored to their original condition.

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